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Temporal Pattern Analysis of Beijing Traffic Guidance Information Released by VMS

Lingling Fan, Shaokuan Chen, Wei Guan*

MOE Key Laboratory for Urban Transportation Complex Systems Theory and Technology, Beijing Jiaotong University, Beijing 100044, China

Abstract

From a statistical point of view, temporal pattern of traffic guidance information under abnormal traffic events is analyzed. Abnormal traffic events include traffic accidents, breakdown vehicles, traffic control, road maintenance and bad weather. In order to study the temporal influence sphere of abnormal events, time duration of Variable Message Signs (VMS) information is analyzed. All our work is based on huge amount of VMS information data in Beijing in the recent three years. The statistical results have practical value in developing time release strategy of traffic guidance information.

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Keywords: Sphere of temporal influence; Duration time; VMS guidance information; Statistical distribution

1. Introduction

Urban traffic guidance system, which can efficiently alleviate traffic congestion and greatly improve the performance of traffic system, is a great part of intelligent transport system (ITS). Variable message sign (VMS), as an infrastructure of urban traffic guidance system, is a main platform to release guidance information. VMS can provide drivers with traffic information, including traffic accidents, breakdown vehicles, traffic control, road maintenance and bad weather, by gathering, processing and disseminating dynamic and nearly real-time traffic information. Meanwhile, traffic information can guide drivers to avoid congested roads, balance the traffic load on network and make the best use of roads resource. Abnormal traffic events are more likely to cause traffic congestion. In order to gradually eliminate the impact of abnormal traffic events on traffic flow, it is necessary study the temporal influence sphere of abnormal events and draw up efficient and effective traffic control

**E-mail address:* weig@bjtu.edu.cn

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program. To a certain extent, the time duration of VMS is equivalent to temporal influence sphere of abnormal events.

The impact of traffic guidance information on traffic flow is ultimately attributed to compliance rate of drivers to guidance information. To determine time duration of guidance information involves two aspects: (1) Under abnormal traffic events, effects of guidance variable message signs (VMS) on driver behavior; (2) Prediction on temporal influence sphere of abnormal traffic events based on drivers' route choice behavior. At present, study on VMS information is currently a hot topic [1-2]. Qualitative and quantitative analysis of the effect of VMS guidance information on drivers' route choice behavior will help us to research dynamic traffic assignment. Based on dynamic traffic assignment, the temporal impact mechanism of VMS guidance information on urban road congestion will be explored. Under abnormal traffic events, study on congestion propagation properties and dissipation of urban road traffic is another hot topic [3-5], which can help to predict temporal impact of abnormal traffic events on traffic flow.

The research of temporal impact of VMS guidance information on traffic congestion is relatively rare. Shang et al [6] use cell transmission model in conjunction with Logit route choice model to analyze the impact of VMS guidance information on traffic congestion, and comparison is carried out between a congestion frequently occurred road and another few congested road. Ye et al [7] qualitatively analyzes impact of dynamic guidance information on congestion propagation, which can improve road condition and reduce personal average network travel expenses under the range of critical flow. Kerner [8] used three-phase traffic flow theory to study the spatial and temporal impact of driver behavior on traffic congestion at bottleneck ramp entrance. Under different congestion mode, the impact of different driving behavior on traffic flow is compared and analyzed.

In this work, from a statistical point of view, based on Beijing VMS guidance information data in recent three years, the temporal pattern of VMS guidance information under abnormal traffic events is analyzed, which has practical value in developing time release strategy of traffic guidance information. The rest of this paper is organized as follows. Section 2 details the Beijing VMS guidance information data. Section 3 analyzes time duration pattern of VMS guidance information. Finally, our conclusions are described in section 4.

2. Data Description

Beijing is one of the largest cities in China. Beijing urban expressway network consists of five loops (the Second Ring Road, the Third Ring Road, the Fourth Ring Road, the Fifth Ring Road and Sixth Ring Road) and 15 urban rapid contact lines. Beijing currently has 337 VMS, located in Beijing's fast and trunk roads. Beijing urban expressway network and locations of VMS are shown in Figure 1. In accordance with urgency degree of abnormal traffic events on traffic flow, Beijing traffic guidance information is divided into three levels:

1st level information: A major traffic accident causes traffic disruption; highway closes because of bad weather; urban trunk hydrocephalus disconnect. These unexpected situations will be released in accordance with 1st level information. 1st level information will be repeatedly released as early as possible through a variety of channels within Beijing city.

2nd level information: Emergencies which have some impact on traffic flow, such as road rush maintenance, road occupation construction, large-scale activities, and traffic accidents. Focused on emergencies, VMS guidance information will be released in a certain area depending on its influence sphere.

3rd level information: which is also called routine traffic information. VMS releases real-time traffic information daily, and intersperses with traffic message and promotional information during nighttime.

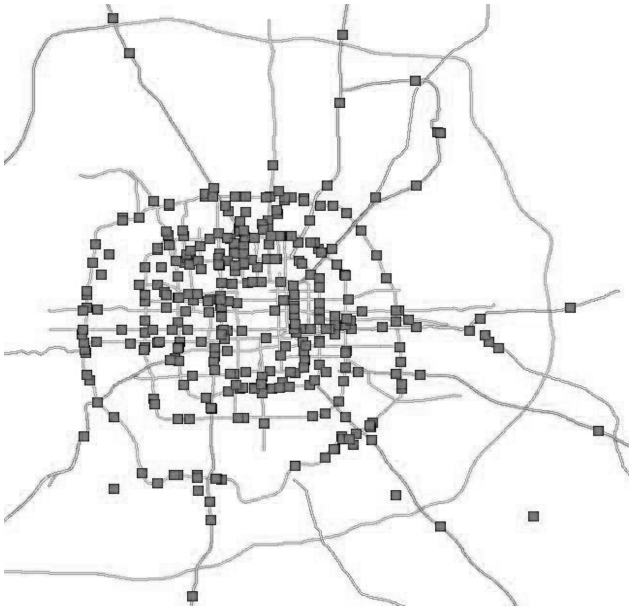

Fig. 1. Beijing urban expressway network and locations of variable message board (VMS is represented by small black boxes)

Beijing traffic guidance information releasing process is as follows: At first, dynamic traffic data detected real time are processed to get traffic flow parameters. Secondly, after model process, the parameters are converted into traffic guidance information according to VMS location and publication requirements. Finally, after audit, traffic guidance information is released by VMS. This process can guarantee security, timeliness, objectivity and accuracy of VMS guidance information. Based on its objective validity, the traffic guidance information data in recent three years are used to research temporal pattern of Beijing traffic guidance information released by VMS. This work extracts VMS guidance information under abnormal traffic events, including traffic accidents, breakdown vehicle, traffic control, road maintenance and bad weather. The statistical summary of the data is listed in table 1. In table 1, time unit length is minute.

Table 1: statistical summary of VMS data (time unit length: minute)

type	sample size	variable	minimum	maximum	mean	standard deviation
traffic incident	22778	time length	0.08	12957.92	20.38	125.84
Breakdown vehicle	45554	time length	0.8	563.28	21.82	31.4
traffic control	23829	time length	0.07	33086.43	33.7	268.3
road maintenance	1286	time length	0.12	175677.02	1041.43	6233.99
bad weather	777	time length	0.1	2543.83	166.48	231.15

3. Time Duration Distribution of VMS Guidance Information

In order to discover temporal influence sphere of VMS guidance information on traffic flow, time duration distribution will be studied. In figure 2, time duration of traffic accident type VMS information is used to make statistics with interval 1 minute, 2 minutes, 5 minutes and 10 minutes respectively. In figure 2 (a) and (b), with time interval 1 minute and 2 minutes respectively, time duration follows logarithmic normal distribution. In figure 2 (c) and (d), with time interval 5 minutes and 10minutes respectively, time duration follows power-law distribution.

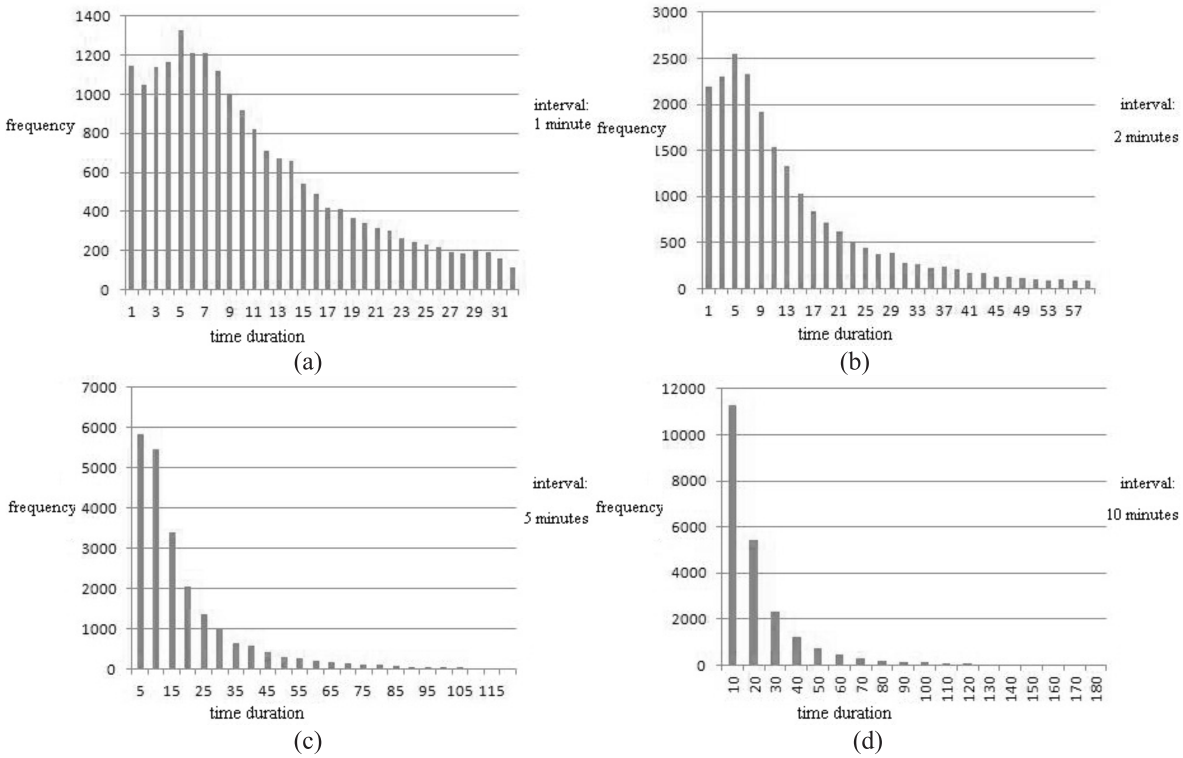

Fig. 2. Time duration of traffic accident type VMS information: (a) interval 1 minute; (b) interval 2 minutes; (c) interval 5 minutes; (d) interval 10 minutes.

For accident type VMS information, the following will inspect the lognormal distribution of interval 1 minute, and calculate the parameters of the lognormal distribution. The probability plot (also known as P-P figure) is used to inspect lognormal distribution. As data points basically fit the diagonal. It shows that expectation of the cumulative probability is very consistent with actual cumulative probability. In others words, interval 1 minute of accident type VMS information follows lognormal distribution. In order to further examine the difference between actual cumulative probability and expected cumulative probability, castration lognormal P-P plot (also known as the cumulative probability of residual plots) is plotted. All the absolute values of the residuals are less than 0.06, indicating good lognormal distribution.

With mean value μ, standard deviation σ, and random variable x, lognormal density function is as follows:

$$\mathrm{f}(\mathrm{x};\mu,\sigma)=\begin{cases}\dfrac{1}{\sqrt{2\pi}\sigma x}e^{-\frac{1}{2\sigma^2}[In(x)-\mu]^2} & \mathrm{x}\geq 0\\ 0 & \mathrm{x}<0\end{cases} \quad (1)$$

Then the parameters of lognormal distribution will be determined, that is, to determine (see equation 1) μ and σ^2. Expectations EX and variance DX of lognormal distribution are as follows:

$$\begin{cases}EX=e^{\mu+\frac{1}{2}\sigma^2}\\ DX=e^{(2\mu+\sigma^2)}\left(e^{\sigma^2}-1\right)\end{cases} \quad (2)$$

Equation (2) is equal to:

$$\begin{cases}In(EX)=\mu+\dfrac{1}{2}\sigma^2\\ DX=(EX)^2(e^{\sigma^2}-1)\end{cases} \quad (3)$$

The calculated parameters of the lognormal distribution are as follows:

$$\begin{cases}\mu=In(EX)-\dfrac{1}{2}\sigma^2\\ \sigma^2=In(1+\dfrac{DX}{(EX)^2})\end{cases} \quad (4)$$

The data of time duration with interval 1 minute can be seen as a set of discrete data, and expectations of the discrete data is shown in formula (5) where x_i is value of time duration and p_i is occurrence probability of x_i. Variance is shown in formula (6). Then the value of Expectations EX and variance DX are taken into the equation (4) to compute μ and σ^2. With interval 1 minute, accident type VMS information follows lognormal distribution, and the lognormal distribution parameters are shown in table 2.

$$EX=\sum_i x_i p_i \quad (5)$$

$$DX=\sum_i x_i^2 p_i-\left(\sum_i x_i p_i\right)^2 \quad (6)$$

With random variable x, power-law distribution of the probability density function is as follows:

$$p(x)=cx^n\left(c,n \text{ are constants}\right) \quad (7)$$

Large amount of studies found that most of random variables in the real world follow negative power-law distribution and density function is as follows:

$$p(x)=cx^{-r}\left(c,r \text{ are constants}\right) \quad (8)$$

Logarithm on both sides of equation (8) will have:

$$Inp(x)=Inc-rInx \quad (9)$$

From equation 9, it can be seen that power-law distribution is a straight line in the double logarithmic coordinates. That is:

$$Inp(x_i) = Inc - rInx_i + \varepsilon_i \tag{10}$$

As the power-law index r need to adopt least squares estimation, the error ε_i will be tested whether relevant and to follow positive state distribution $N(0, \sigma^2)$. Durbin-Watson method is used to test autocorrelation and linear regression equation's standardized residuals P-P figure is used to test residuals. After test, linear fitting equation is as follows:

$$Inp(x) = 1.756 - 1.638Inx \tag{11}$$

P-P probability plot is used to test residuals, and residuals obey approximate normal distribution. Therefore, accident type VMS information with interval 5 minutes follows power law distribution.

Using similar method, followed by breakdown vehicle, traffic control, road maintenance and bad weather to be made statistical analysis, the final results are shown in table 2.

Table 2. Time duration distribution of various types of VMS traffic guidance information

type	distribution				
	1 minute	2 minutes	5 minutes	10 minutes	30 minutes
traffic incident	lognormal distribution $\mu = 2.18$ $\sigma^2 = 0.39$	lognormal distribution $\mu = 2.29$ $\sigma^2 = 0.62$	power law distribution $c = 1.76$ $r = -1.64$	power law distribution $c = 3.74$ $r = -2.01$	——
breakdown vehicle	——	——	power law distribution $c = 0.65$ $r = -1.20$	power law distribution $c = 4.33$ $r = -1.93$	——
traffic control	——	lognormal distribution $\mu = 2.51$ $\sigma^2 = 0.46$	lognormal distribution $\mu = 2.54$ $\sigma^2 = 0.51$	power law distribution $c = 4.11$ $r = -2.17$	——
road construction	——	——	——	——	——
bad weather	——	——	——	——	power law distribution $c = 1.93$ $r = -1.03$

4. Conclusion

In this work, Beijing VMS guidance information data in recent three years are used to analyze temporal pattern of VMS information under abnormal traffic events. In order to study temporal influence sphere of abnormal traffic events, time duration pattern is analyzed. Most of VMS information shows obvious statistical distribution characteristics. The results of this work have practical value to develop time release strategy of traffic guidance information.

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References

Erke, A., Sagberg, F., Hagman R. (2007). Effects of route guidance variable message signs (VMS) on driver behavior, *Transportation Research Part F*, vol.10, no.6, pp.447-457.

Shi, W., Wu, J., Zhou, S., Zhang, L., Tang, Z., Yin, Y., Kuang, L., and Wu, Z. (2009). Variable message sign and dynamic regional traffic guidance, *IEEE Intelligent Transportation System Magazine*, vol.1, no.3, pp.15-21.

Wright, C., Roberg, P. (1998). The conceptual structure of traffic jams, Transport Policy, vol.5, no.1, pp.23-38.

Roberg-Orenstein, P., Abbess, C., R., Wright, C. (2006). Traffic jam simulation, *Journal of Maps*, pp.107-121.

Long, J., C., Gao, Z., Y., Zhao, X., M., Lian, A.,P., Orenstein, P. (2008). Urban traffic jam simulation based on the cell transmission model, Networks and Spatial Economics, vol.11, no.1, pp.43-64.

Huayan, S., Haijun , H., Ziyou, G.(2008). Impacts of variable message signs on traffic congestion, *Science in China Series E*: Technological Sciences, vol.52, no.2, pp.477-483.

Xaofei, Y., Jun, C. (2011). Analysis on traffic congestion propagation influenced by traffic congestion information, International Conference on Electric Technology and Civil Engineering (ICETCE), pp. 3883 - 3886.

Kerner, B., S. (2010). Effect of driver behavior on spatiotemporal congested traffic patterns at highway bottlenecks in the framework of three-phase traffic theory, *Physics and Society*.